ADDRESS OF THE RETIRING PRESIDENT OF THE SOCIETY, IN AWARDING THE BRUCE MEDAL TO PROFESSOR J. C. KAPTEYN.

By Heber D. Curtis.

Americans are firm believers in all that is implied in the expression, "the man behind the gun," and none of us are inclined to deny that the man is, in general, more important than his equipment. But, while always ready to admit the truth of this familiar phrase, it must be said that we, as a people, are very prone to be dazzled by mere bigness; we are too apt to feel that our universities are necessarily great merely because of the great numbers of students which many of them have; that our laboratories are necessarily world-famed because of the magnificence of their equipments. Holland is not a large country. It possesses four universities; we have in America at least half a dozen universities, each of which has more students, and perhaps more buildings and equipment, than all four of Holland's universities taken together. But a casual survey of the faculty lists of these four Dutch universities shows a striking number of world-famous names in certain fields of science; it is doubtful if we could pick out in four great American universities an equal number of men who could take rank with such names as Lorentz, Kammerlingh-Onnes, De Vries, Van der Waals, or Zeeman.

The popular idea of an astronomer is that of a man whose work is entirely at night time, with a telescope; the larger the telescope, the greater the astronomer; a point of view which is very far from representing the whole truth. Observations, by themselves, unless properly studied and subjected to calculation, are not of very great value, and in most lines of astronomical work sufficient observations can be secured in one night to keep the observer busy for a week at his desk. Naturally, without the observations which form its foundation, there could properly be no astronomical science as we know it, but there is also the need for keen minds to piece together and arrange in order the facts collected by observation from

the millions of separate units which form our universe, to study the greater equations of our cosmos. The Bruce Medal, which is bestowed by the Astronomical Society of the Pacific for distinguished services to astronomy, has now been awarded to ten famous astronomers, and it is worthy of note that four of the ten might properly be termed astronomers without a telescope, men who, at the time of their greatest work, seldom or never looked through a telescope. One of these, a world-famous mathematical astronomer, once said jokingly that he was rather doubtful whether he would be able to pick out the correct end of a telescope to look through.

The University of Groningen, Holland, is the smallest of the four Dutch universities; its students number about five hundred. In a few rooms of a building in this city is located the Astronomical Laboratory of Groningen, a department whose annual stipend from the university in 1906 was only about $1,000 a year. It is in truth an observatory without a telescope; its only instruments are three microscopes for measuring photographic star plates. Modest as is the equipment, the Publications of the Astronomical Laboratory at Groningen are well and favorably known to astronomers the world over. Professor J. C. KAPTEYN is the director of this Astronomical Laboratory, and in connection with the bestowal of the Bruce Medal of the Astronomical Society of the Pacific upon Professor KAPTEYN, it will be of interest to review briefly some points of the work which has been accomplished by this astronomer, with very modest equipment and resources.

It has been said that the perfectly pure note of a fine violin or the voice of a great singer can always be easily heard above the complex of sounds given by the greatest accompanying orchestra, and, similarly, a life devoted solely and purely to one ideal is pretty certain to make itself felt. I can give you to-night no better idea of the devotion to astronomical science which has always characterized our medalist than to quote some passages of the correspondence which passed between Professor KAPTEYN and Sir DAVID GILL in connection with the great Photographic Durchmusterung of the Observatory of the Cape of Good Hope.

This was nearly thirty years ago, and the possibilities of the

THE ASTRONOMICAL LABORATORY AT GRONINGEN.

photographic plate as a means of mapping of the stars of the sky were just being realized. Sir DAVID GILL was anxious to apply this new photographic method to the charting of the stars of the southern heavens; while the Cape Observatory had sufficient funds to provide for taking the photographic plates which should cover the entire sky from declination — 19° to the South Pole, there was no money available to provide for the tremendous task of measuring and reducing the star images on these plates. The final catalogue contains more than 450,000 stars.

It was at this juncture that Professor KAPTEYN offered his help. I will here quote some extracts from his letter to Sir DAVID GILL:—

I have still to explain to you the proposal in my former letter, which I thought it better not to postpone—my resolution being taken. In doing this you will excuse me for premising so much about my private circumstances as seems necessary for the purpose.

In the year 1878 I was appointed Professor of Astronomy and Theoretical Mechanics at the University of Groningen, having been before, during a couple of years, observer at the Leiden Observatory. Directly on my appointment I proposed to the government to fit out a little observatory. . . . Perhaps I shall succeed after some years in getting one or two instruments with which truly scientific work may be prosecuted; but at all events a very long time will have to elapse before any such result may be looked for. The first years of my professorship once passed, my lectures left me considerable leisure, which it has always been my desire to devote to astronomical observations. . . . Now, after your success in stellar photography, and especially after your letter in which you tell me, "I am obliged to crave help where I can get it," it has occurred to me that by measuring and reducing your photographs I could contribute very effectually toward the success of an enormous and eminently useful undertaking. Since then I have revolved the idea in my mind and I have come to the conclusion that if you will let me, and if I can secure the necessary help, there is no one in better condition to undertake this work than myself. . . .

I have kept this letter here some days to talk the matter of the Photographic Durchmusterung over with Professor BAKHYUZEN and his brother. I am bound to say that they were not very enthusiastic over the matter; of course, they thought the results, once reached, of immense value, but the drudgery to be gone through before these results are once got into the form of a catalogue is almost unbearable. However, I think my enthusiasm for the matter will be equal to (say) six or seven years of such work. . . .

The three great volumes of the Cape Photographic Durchmusterung to-day form a worthy memorial to Professor KAPTEYN's single-hearted devotion to his chosen life work. An astronomer without instruments, he did not let this lack keep him from the attempt to do valuable work wherever he could find it to do. It was not a class of work affording the same vivid interest to the investigator as that which is given by many other lines of research; it was in no sense popular, in the common acceptance of that term, but hard, monotonous routine. The completed work took over twelve years instead of the six or seven which KAPTEYN had anticipated; the two rooms in which the work was carried on were loaned to Professor KAPTEYN by a fellow professor at Groningen, so that the Cape Photographic Durchmusterung, strange as it may sound, as far as the catalogue is concerned, may be said to have emanated from the Physiological Laboratory at Groningen.

Like every other science and every other occupation, the science of astronomy is to-day highly specialized. It has been stated that the death of the great mathematician SYLVESTER marked the passing of the last man who could be said to be truly an authority in every branch of the mathematics of his day, and no mathematician to-day pretends to be thoroughly conversant with more than one or two fields of this vast and complex science. The case in astronomy is much the same. The modern astronomer, frequently an entire observatory, to-day devotes energy to one rather narrowly limited field, and attempts few observations on other fields. To illustrate: At the start the Lick Observatory took daily photographs of the Sun, but discontinued this about ten years ago, and the photoheliograph has since been dismounted, solely for the reason that the same work was being done at other observatories with equal or more powerful equipments, and it seemed wiser to expend our efforts on lines of work which could be better done here than elsewhere, and to avoid useless duplication.

There is, however, one greater aspect of the subject as a whole toward which all astronomers are more or less indirectly working, an astronomy into which some day all the results from the lesser divisions of this science will finally fit, each fragment of knowledge gained by minute specialization tend-

ing to form a harmonious whole, a perfect pattern. In this greater field are combined our studies as to the nature and size of our stellar universe, its past, and future history.

How large is this universe of stars in which our Sun forms so inconspicuous a unit? Is it finite or infinite? Is there some plan underlying the whole, or is the arrangement of these millions of separate units merely a haphazard one? How has our universe attained its present form, and what can we say of its probable future history? All these form a part of the greater questions which astronomy is trying to answer, and toward the correct answer to these questions are directed all the minute researches on this or that star, the observations made with hundreds of telescopes, the mathematical researches, the dry bones of statistics, which, to the lay mind, seem so far removed from the interesting observations and speculations which make astronomy so popular a subject. Astronomy has not yet answered all these greater questions, and perhaps may never be able to answer them fully.

It is in the study of some of these greater problems of our stellar universe that Professor KAPTEYN has done much of his most valuable work. His observatory has been his desk and a room fitted with instruments for measuring photographic plates; his subject-matter photographic plates and observations of star positions made by other astronomers; his tools the methods of mathematical analysis.

A great deal of our medallist's most valuable work has been in the field of stellar motions; it is not easy to give many of the details of these researches or to indicate the full measure of their difficulty without introducing technicalities of little interest to the general reader. However, a few simple comparisons may perhaps be of service in indicating the minuteness of the data which form the subject-matter of such researches, investigations to which each advance in our astronomical knowledge seems to add new complexities. The workings of the law of gravitation, as exemplified in our solar system, are now so well known that it is not a very difficult task for the astronomer to tell quite accurately in what part of the sky a given planet was at a certain date one thousand years ago, or where it will be one thousand years from now. But there is no such apparent

regularity in the phenomena of our stellar universe. The small proper motions of the stars appear at first sight to be entirely at random. We know from the spectrograph that the radial motions may average five to ten miles in every second of time, but the distances are so inconceivably great that actual movements amounting to billions of miles will, in general, change their apparent positions in the sky by amounts almost too small to measure. To illustrate: If we, in San Francisco, were able with our telescopes to see a man in Los Angeles, and that man were to move a distance of ten feet in one year's time, it would appear to us that this motion was inconceivably slow, and impossible of detection. This would, however, be a very large "proper motion" as compared with the actual movements of the stars; in fact, there are only about one hundred stars known which would move, in one year, over a space in the sky which would look as large as ten feet would in the distance from San Francisco to Los Angeles. For the average naked-eye star the motion across our line of vision would correspond more nearly to about six inches a year when seen at this distance. Impossible to measure with any telescope, you may say. This is true, if we were to try to measure only the six inches moved by our hypothetical Los Angeleno in one year, but in one hundred years the accumulated effect would amount to fifty feet, still a very small quantity, but possible to detect. So with the minute proper motions of the stars; imperceptible in most cases in a year's time, these motions come within the reach of our measuring instruments when sufficient time has elapsed. So it turns out, that for the solution of some of the questions as to the size of our universe and the motions of the stars which form it, carefully made old observations of a star's position become very valuable. The patient astronomers, who, for one hundred and fifty years past, have carefully observed the accurate positions of the stars, builded better than they knew; their observations will never entirely lose their value, though few of these observers doubtless dreamed of the precise way in which their dry routine of observation would help in solving the problems of a hundred years in the future. These minute proper motions will, after a great lapse of time, completely change the aspect of certain constellations as we know them

now. Five stars of the familiar Big Dipper are moving in one direction in common, while the other two are moving toward a different part of the sky; so it is that an observer two hundred thousand years ago, or one two hundred thousand years from now, would look in vain for this familiar configuration of stars as we see it to-day.

The problem of finding the laws governing these apparently haphazard and very minute motions is a very complicated one; it is much as though we had set before us the problem of determining the law governing the arrangement and movements of a large swarm of gnats or fireflies.

At present we know with considerable accuracy the minute proper motions across our line of vision for several thousand stars, and one of the greater questions which astronomy must answer in its attempt to portray the size and structure of this universe of stars is whether any law governs these apparently random movements. This is the field in which Professor Kapteyn has made some of his most striking discoveries. I have tried to indicate, in a general way, how complicated and difficult this question is; a further cause of complexity is introduced by the fact that our Sun and its system is, like other stars, not at rest, but moving toward a point in *Hercules* at a rate of about twelve miles in every second of time, and the effect of this motion must be removed from the observed proper motions of the stars. With so many small motions of varying directions and amounts, the problem becomes largely one of averages, and the methods statistical. The stars must be sorted out by magnitudes and spectral classes, then again by the size and general direction of their proper motions, taking into account our rather meager knowledge of stellar distances. By such statistical methods of sorting and arranging the stars in terms of their motions, positions, brightness, and age as shown by their type of spectrum, Professor Kapteyn has made a number of striking contributions to modern astronomy; perhaps the best known of these is his discovery that the brighter stars show a well-defined tendency to move toward two diametrically opposed points in the sky, rather than entirely at random. These two points of preferential motion are in the Milky Way; one of them being about seven degrees northeast of the bright star

Betelgeuze in *Orion*, and the other one at the antipodal point on the other side of the celestial sphere, north of the constellation of *Sagittarius*. Many other investigators have since studied this problem, and the evidence of the spectrographic results in general supports this two-drift theory, but do not indicate it so strongly as do the proper motions. There is also a well-marked tendency for many of the stars to move in planes roughly parallel to that of the Milky Way, but recent results tend to show that stars of different ages behave differently in this regard.

Professor KAPTEYN's results on star-streaming were secured, as I have said, by what we may term statistical methods applied to the very minute proper motions of the stars. There is one fault in such methods, which lies in the fact that the apparent motion of a star in space tells us nothing as to the distance of the star or its actual motion in miles per second, unless we have knowledge as to the distance of the star from other sources. A simple illustration may make this point clear; a motion of one second of arc per year across our line of vision would be equivalent, if we were looking, for example, at the branch of a tree one hundred feet away, to a motion or growth of only one two-hundredth of an inch per year; at the distance of the Sun it would equal four hundred and fifty miles per year; while for a star one hundred light years away, it would mean a motion of nearly three billion miles per year, or ninety miles a second. Now, the spectrograph enables us to tell in miles per second how fast a star is moving directly toward or directly away from us, no matter what the distance of the star may be. So it is that a combination of our knowledge of the proper motions of the stars with the values of the actual radial velocities in miles per second secured by the spectrograph has in recent years given us more accurate values of the real motions and average distances of the stars. For this reason some of Professor KAPTEYN's conclusions, particularly with regard to the size of our stellar universe, have been somewhat modified in recent years, but this fact in no way detracts from the value of the methods which he has applied and where he has in many cases pointed the way to future ad-

vances when our knowledge of radial velocities shall be relatively as complete as in the case of stellar proper motions.

Other valuable pieces of work carried through by our medallist are his extensive researches on the proper motions of the stars by means of photography, and also his researches on stellar parallax by the same method.

It was KAPTEYN, too, who perhaps first fully realized the difficulties which bar our way to future progress in the knowledge of these greater problems of stellar distribution, type, distance, and motion, for this knowledge seems absolutely beyond our finite resources should we attempt to find out everything about every star. With a total number of stars generally estimated at about two hundred million, should these be investigated individually it would be centuries before all the observatories of the world could begin to find out all we wish to know in our efforts to fathom the plan or plans underlying our universe of stars. We ought to know a great number of proper motions, and we now know such motions accurately for only a few thousand stars; we ought to know their stellar age as given by the type of spectrum which they show, and this we know for fewer than ten thousand stars at present, though the work at Harvard will bring this number up to about 140,000 in the near future; we ought to know their actual speed in miles per second, and the spectrograph has thus far given us fewer than two thousand radial velocities; we ought to know the distances of many of them, and thus far we know the individual distances of fewer than two hundred stars with any accuracy, and these distances are for our nearest stellar neighbors. All these gaps in our knowledge make it seem like a task too great for mankind ever to gain more than a superficial knowledge of the real nature and structure of this universe of stars. But now suppose that instead of trying to find out these facts for most of the stars of the sky, we select quite a number of relatively small sections of the sky distributed very uniformly over the heavens, and suppose further that the main observatories of the world so combine their efforts as to find out for all these small representative squares everything that can be found out with reference to the proper motions, radial velocities, spectral types, and distances of the

stars in each square. From a general average of the fairly complete knowledge which would thus be secured for these representative sections of the sky we should then have data which would enable us to learn the laws of this stellar universe almost as accurately as though we had attempted the impossible task of studying, if not every star, at least a very large proportion of the stars. This plan of systematizing the ascertainable facts of our stellar universe by co-operative studies on numerous small representative sections of it is due to our medallist, and is known as KAPTEYN's Plan of Selected Areas; already a number of observatories are concentrating their efforts on these areas. Some such subdivision of the task and concentration of effort on relatively small representative areas seems to offer us the only means of solving the problems of an infinite universe with only finite time and finite resources at our disposal.

Let us now attempt to give briefly a conspectus of the more salient features of this universe of stars; many points are still uncertain, and the astronomer prefers to state many of his conclusions as only probably true, in view of the fact that for many of his deductions the data thus far gathered forms only a beginning.

The first point which should be emphasized is the essential oneness of the stellar universe in its subject-matter. In the spectrum of the Sun we find great numbers of absorption lines which we know stand for certain chemical elements, iron, calcium, hydrogen, etc., and to the best of our knowledge the light given forth by burning iron, for example, will show the same lines in our laboratories here on Earth as it will in the far greater laboratory of a star at the limit of our visible universe. It is probable that all the elements we know are present in the Sun, though not all have been identified as yet. There are only about eighty-three elements or kinds of matter known to us; just why there should thus be so small a number of arrangements of atoms instead of an infinite number of kinds of matter, the chemist and physicist can not yet explain. Similarly, we find stars, and many of them, distant billions of billions of miles from us, which show essentially the same spectrum as our Sun. A still larger number of stars show the

lines of fewer elements, mainly hydrogen, magnesium, calcium and helium, and there are still left lines which we cannot yet identify with known terrestrial elements, but such unknown lines are relative few, and we expect eventually to be able to identify even these. For a long time, to illustrate, certain lines were observed in the spectrum of the Sun and many stars which had no counterpart on the Earth; the unknown element was called helium. Years later physicists discovered small amounts of this gaseous element on the Earth. The nebulæ offer many puzzles not yet explained, and it may be, as a few astronomers have argued, that we here see matter beginning to be, in forms and conditions yet unknown to us, but for the stars we may say that, for distances out into space so inconceivable that light needs thousands of years to make the journey, the stars show a oneness with the materials which make up our own Sun and Earth; like our Earth, the stars evidently are formed of only a finite number of kinds of matter. Though we to-day accept this fact as almost self-evident, this oneness of the matter in the tremendous reaches of space is an inspiring fact and full of meaning.

Secondly, we discern everywhere in this universe of stars the evidences of a process of evolution, a cycle, perhaps recurrent, of growth and decay. From the formless nebula and the great expanses of diffused nebulosity, through the spirals, to the clusters and such stars as the Pleiades with the remnants of their original nebulosity still surrounding them, the evidence of an evolutionary process seems clear, though we know little as to the actual laws governing the growth. Of the brighter stars, at least one in every four is a double star; whether this proportion continues among the fainter stars we have no means of knowing, but there is certainly a strongly marked tendency for the fission of the parent mass into two suns of nearly equal size.

Thirdly, these millions of suns are moving in all directions at speeds of from five to ten or more miles in a second. There are great groups of suns whose separate units are light-years apart which are traveling together through space; such groups, for instance, as the great *Taurus* group discovered by Boss, or those aggregations which KAPTEYN found with motions tending

toward his vertices of preferential motion. Here, perhaps, the most striking fact is that the speed appears to be a function of the star's spectral type; the older the star, the higher its speed in space. As pointed out by CAMPBELL and KAPTEYN, it is as though matter in the ante-stellar state were in some way not subject to the attraction of gravitation.

Finally, when we attempt to visualize the dimensions of this universe of stars, we must confess that our knowledge is most fragmentary and imperfect; at present we know the distances of only those stars which form the inner fringe of the stellar universe in which our Sun is but a very inconspicuous unit. Our present direct methods enable us to determine the distances of stars with some confidence out to about one hundred and fifty light-years, nearly a quadrillion miles, but beyond this distance but little confidence can be felt in direct determinations of stellar distances. By combining the results of proper motions and radial velocity data it is possible to find the average distances of large groups of stars. The brighter stars of solar type have an average distance from us of about one hundred light-years (the ten nearest stellar neighbors of the Sun would be contained in a sphere twenty-five light-years in diameter), while the younger Class B stars are on the average about five hundred light-years from our system. Eventually this method will enable us to determine distances still farther out in space, perhaps to one or two thousand light-years, but here there appears to be a wall which may bar all further progress by known methods. This is because for the fainter and more remote stars it becomes increasingly more difficult to photograph them with the spectrograph, and the proper motions are doubtless so minute that several centuries of observation instead of one century may be necessary. Beyond the confines of a sphere about one thousand light-years in diameter, then, we really know nothing to-day; our estimates of the probable size of the visible universe are all but little more than guesses, all rest on more or less probable assumptions. We can be guided only by the analogy of our own Sun, which at the distance of the average naked-eye star would be visible only in a telescope, and by what little we already know of star distances, with more or less probable hypotheses as to the existence and

amount of an absorption of light in space. So it is that for the probable diameter of the belt of stars which forms the Milky Way the estimates vary all the way from three thousand to at least a million light-years.

Such researches apparently do not touch, even remotely, the daily life of this practical age. But if to know, or even to know that one knows, is power, a knowledge of these greater facts of our universe is certainly an asset of great, though indirect, value to our social fabric. The Sun is not swallowed up by a great dragon at the time of an eclipse; the aurora is not a procession of departed spirits trooping across the sky; the Sun and the stars do not revolve in their crystal spheres about an Earth which is the center of all. To realize, even in part, the majesty of this universe of stars is a possession of value to the soul of any man.

PROFESSOR J. C. KAPTEYN.

THE BRUCE GOLD MEDAL